STATE OF ILLINOIS

Rivers and Lakes Commission

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FLOOD CONTROL FOR PECATONICA RIVER

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REPORT OF

Rivers and Lakes Commission

ON

PECATONICA RIVER

FOR

FLOOD CONTROL

Arthur W. Charles, *Chairman*
LeRoy K. Sherman, *Commissioner*
Thomas J. Healy, *Commissioner*
Charles Christmann, *Secretary*

Survey and Investigation by
Rivers and Lakes Commission and State Geological Survey.

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General Views Along Pecatonica River.

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ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

Hon. Edward F. Dunne, Governor of the State of Illinois, Springfield, Illinois.

DEAR SIR: At the request of the Pecatonica River Relief Association of Stephenson County, and in view of the serious damage caused every year by the overflow of Pecatonica River in the vicinity of Freeport, The Rivers and Lakes Commission has made a careful survey and study of the river and has issued this bulletin No. 18 on "Flood Control for Pecatonica River," presenting briefly the results of this study with an outline and estimate of a definite plan for controlling the flood waters through the city of Freeport.

Respectfully submitted:

RIVERS AND LAKES COMMISSION OF ILLINOIS.
ARTHUR W. CHARLES, *Chairman.*
LEROY K. SHERMAN.
THOMAS J. HEALY.

CHARLES CHRISTMANN, *Secretary,*
905, 130 North Fifth Avenue, Chicago, Illinois.
December 1, 1916.

INTRODUCTION.

The frequent recurrence of more or less damaging floods along the bottom lands of the Pecatonica valley has been a source of great annoyance and financial loss to the residents and property owners for a number of years. In 1914, the Rivers and Lakes Commission made a survey of the river from a point 14.5 miles above Freeport to Brown's Dam, 11.6 miles below the city, to determine the effects of Goddard's Dam and Brown's Dam in causing overflow damage, and also to study the general flood conditions of the valley. At the request of the Pecatonica River Relief Association of Stephenson County a further reconnaissance of the valley was made by this commission under the direction of J. P. Ball, assistant engineer, for the purpose of developing a definite plan of flood relief. Before the completion of this work a flood of unprecedented height occurred in March, 1916, causing damage that, in the city of Freeport alone, was estimated at over $100,000. Careful observations and measurements were taken during this flood by H. C. Beckman, junior engineer, U. S. Geological Survey, working in cooperation with this commission, and further investigations as to its effects were made by Mr. Ball.

This bulletin is compiled from the results of these investigations and presents a definite plan for the prevention of further flood damage at Freeport with an estimate of the outlay required for its execution. In the preparation of this work maps and profiles of the river below Freeport,[1] made by the U. S. Geological Survey in cooperation with the State Geological Survey, have been of great value. Acknowledgement is made to Mr. Chas. S. Hepner, city engineer of Freeport, and a number of the residents of the valley for valuable infomation relative to damages sustained, high water marks, etc., and to the engineering department of the Illinois Central Railroad Company, the Chicago & North Western Railway Company and the Chicago, Milwaukee & St. Paul Railway Company for railroad maps furnished by them.

SUMMARY OF CONCLUSIONS.

The general conclusions regarding the flood situation in the Pecatonica valley, as more fully developed in the body of this report, may be briefly stated as follows:

1. That the greatest known flood in the history of the Pecatonica valley occurred on March 28, 1916, the water reaching a height of 19.4 feet on the Freeport gage, with a corresponding discharge of about 17,000 cubic feet per second.

2. That this discharge was produced bv a comparatively small rainfall amounting to less than two inches in three days over the upper drainage area, accompanied by a marked rise in temperature, at a time

[1] Copies may be obtained from State Geological Survey, Urbana, Ill.

when the ground was sealed with ice and frost and covered with about five inches of snow.

3. That the probability of the occurrence of a much greater rainfall under similar run-off conditions is comparatively remote, and the construction of controlling works to protect the valley from inundation in such a contingency is financially impracticable.

4. That the river, in its natural state, spreads out over the whole valley during flood periods and the tendency is toward a general increase of flood height and property damage due to the silting up of the channel and the encroachments of civilization.

5. That the benefits to be derived from a general project designed to prevent the inundation of the bottom lands of the valley as a whole would not, at the present time, be commensurate with the cost of such work, but the annual damage sustained at Freeport and vicinity is sufficient to warrant the outlay necessary to protect that city against a flood flow of 21,000 cubic feet per second, or nearly 25 per cent greater than that of March 28, 1916.

6. That this protection can best be accomplished by providing channel area sufficient to carry a flood of 21,000 cubic feet per second with a slope of approximately 0.5 foot per mile through Freeport and, where necessary, constructing levees to protect the low sections of the city against overflow.

7. That the required cross section can be most economically obtained by constructing an auxiliary channel through East Freeport as the enlarging of the old channel, on account of the limited width available and the many obstacles to be overcome, would involve an expenditure much greater than that required for an auxiliary channel.

8. That this project, more fully detailed in the body of this report, will protect the city of Freeport against the greatest flood that can be reasonably expected at a cost of not more than $500,000, and the expenditure of this amount is warranted by the value of the protection secured.

9. That the carrying out of this project would not aggravate the flood conditions in the valley below nor interfere with possible future activities for flood control at other points.

THE RIVER AND ITS INDUSTRIAL DEVELOPMENT.

DESCRIPTION.

The Pecatonica, or, as the Indians originally named it, "Peekeeonikee," meaning "a stream of curious moods and antics," rises among the highlands in the southwestern part of Wisconsin, flowing in a general southerly direction as far as Freeport, thence northeasterly to the point where it empties into the Rock River just above Rockton. Its total length is about 158 miles, 66 miles in Wisconsin and 92 miles in Illinois. With its tributary streams it drains 2,610 square miles of which 816 are in Illinois. Its principal tributary streams in Illinois are:

Richland Creek, entering north of Freeport and draining 137 square miles of which 79 are in Illinois.

Yellow Creek, entering south of Freeport, about 32 miles in length and draining 190 square miles.

Rock Run, entering near the village of Pecatonica, 13½ miles long and draining 89 square miles.

Sugar River, entering about six miles west of Rockton with its drainage area largely in Wisconsin.

The drainage basin of the Pecatonica in the State of Illinois covers practically the whole of Stephenson County and nearly half of Winnebago County, but inasmuch as the headwaters and by far the greater portion of the total drainage area of the stream lie in Wisconsin, the variations in the flow are governed largely by the physical and climatic conditions of that state.

The total fall of the river from the extreme headwaters in Wisconsin to its junction with the Rock River is about 500 feet, although within the State of Illinois the fall is only about 55 feet.

NAVIGATION.

In the original government survey the Pecatonica was meandered and classed as a navigable stream, and, in the deeper portions, small motor craft are in use for pleasure purposes at the present time, but in 1884 reports from the U. S. engineers showed that the river was not worthy of improvement in that respect and navigation of the stream not a public necessity.

FISHING.

Little or no commercial fishing is carried on in the waters of this stream, and though most of the various kinds of fish common to Illinois may be found at many points in its course, the Pecatonica, as compared with other streams of the State, is of little value to the fishing industry.

POLLUTION.

The question of stream pollution has not yet reached a critical stage as there are but few large towns in the drainage basin. At Freeport the sewage, both domestic and industrial, discharges through various outlets directly into the river. In February, 1914, the Rivers and Lakes Commission approved plans allowing the discharge of an untreated 24-inch sewer into the river at that city, subject to the stipulation that, if at any time the pollution becomes objectionable the city shall install a suitable disposal plant.

INDUSTRIES.

The rich alluvial soil of the bottom lands and the good railroad facilities encourage extensive farming and grazing, and with the exception of the city of Freeport the whole valley is devoted largely to the raising and manufacture of dairy products. The U. S. Census Report for 1910 shows the proportion of farm land in Stephenson County to be between 95 and 100 per cent, and in Winnebago County, between 80 and 90 per cent, and the average value of land for both counties between $75 and $100 per acre. Both Stephenson County and the city of Freeport have shown a steady growth in population,

DATA ON BRIDGES CROSSING THE PECATONICA IN ILLINOIS.

Name and location.	Miles above month.	Spans.	Type.	Abutment.	Water opening between abutments.	Elev. low iron.	El. high-water mark.	Built.	Remarks.
Harrison Highway at Harrison	8.50	2	Steel Truss	Stone	178.0	731.55	730.88	1887	Pier Width 6 Feet.
Trask Highway	19.75	1	Iron Bow String	Pile	119.0	738.15	736.10	....	Pile approaches, 2 Bents Each.
Pecatonica Highway at Pecatonica	32.70	4	Concrete Arch	Concrete	224.0	743.85	742.13	1912	
Farwell Highway Near Ridott	39,80	1	Steel Truss	Stone	151.5	749.07	746.80	1883	
Ridott Highway near Ridott	46.25	1	Iron Truss	Stone	157.0	750.60	750.39	1883	
Rockford & Interurban	49.50	1	Steel Truss	Pneumatic Tubes	128.0	753.02	750.86	....	Pile approaches, L. 18 Bents R. 1 Bent.
Chicago & Northwestern	49.51	2	Steel Truss	Stone	240.0	754.92	750.86	....	Pier Width 6 Feet.
Chicago & Northwestern	61.25	2	Through Plate Girder	Concrete	183.2	759.48	759.10	....	
Gund Avenue Highway at Freeport	61.50	1	Steel Truss	Pneumatic Tubes	160.0	758.17	759.21	1896	Gaging station.
Chicago, Milwaukee & St. Paul	61.80	3	Through Truss	Stone	318.0	759.57	759.10	1895	
Stephenson Street	62.00	3	Girder with Concrete Floor	Stone	207.2	758.70	760.35	....	Approaches--Paved Street 1 Pier—Stone. 1 Pier Pneumatic Tubes.
Transfer Railroad	62.20	2	Through Truss	Concrete	208.0	759.20	760.90	....	
Cedarville Road Highway	62.60	1	Iron Truss	Stone	193.0	771.09	760.94	1885	
Illinois Central	66.60	1	Steel Truss	Stone	124.0	763.34	762.34	1886	
Harlem Highway	70.10	1	Steel Truss	Stone	110.0	776.37	766.49	....	
Rigney's Highway	73.40	1	Steel Truss	Concrete	136.0	769.17	768.21	....	
Damascus Highway	74.40	1	Steel Truss	Stone	175.0	770.77	769.03	1884	
McConnell Highway	82.25	1	Steel Truss	Concrete	136.0	772.30	775.60	....	
Illinois Central	85.05	1	Steel Truss	Pile	156.0	775.30	778.55	....	200 Feet Pile Approach Each Side.
Winslow Highway	90.50	1	Steel Truss	Stone	183.0	779.50	780.26	1889	

valuation and revenues. At the present time Freeport has a population of about 22,000 with 61 industrial plants employing more than 3,200 people. The following other communities are located on the river and its tributaries:

Pecatonica River.		Richland Creek.		Yellow Creek.	
Name.	Pop.	Name.	Pop.	Name.	Pop.
Pecatonica	1,200	Orangeville	400	Pearl City	500
Winslow	500	Buena Vista	150	Kent	170
McConnell	350	Red Oak	150		
Ridott	180	Sciota Mills	150		
Shirland	110				

RAILROADS.

The Illinois Central Railroad is the chief transportation factor in the valley. The headquarters of the first division of the line from Chicago to Omaha with terminal and roundhouse facilities are located at Freeport. From this point branch lines run to Dodgeville, Wisconsin, and Madison, Wisconsin, and the old charter line south to Cairo. The Chicago, Milwaukee & St. Paul Railroad enters the valley near Rockton, following the bottom lands up to Freeport where it crosses the river and continues to Savanna, Illinois. A branch of the Chicago & Northwestern Railway, running from Chicago to Freeport, enters the valley at Pecatonica. The Chicago & Great Western Railroad passes about four miles south of Freeport. The Freeport & Rockford Interurban Railroad parallels the Chicago & Northwestern from Pecatonica to Freeport.

DAMS AND WATER POWER.

There are many small dams on the various streams of the Pecatonica basin in Illinois, but at only three of these is the water power, at present, being used.

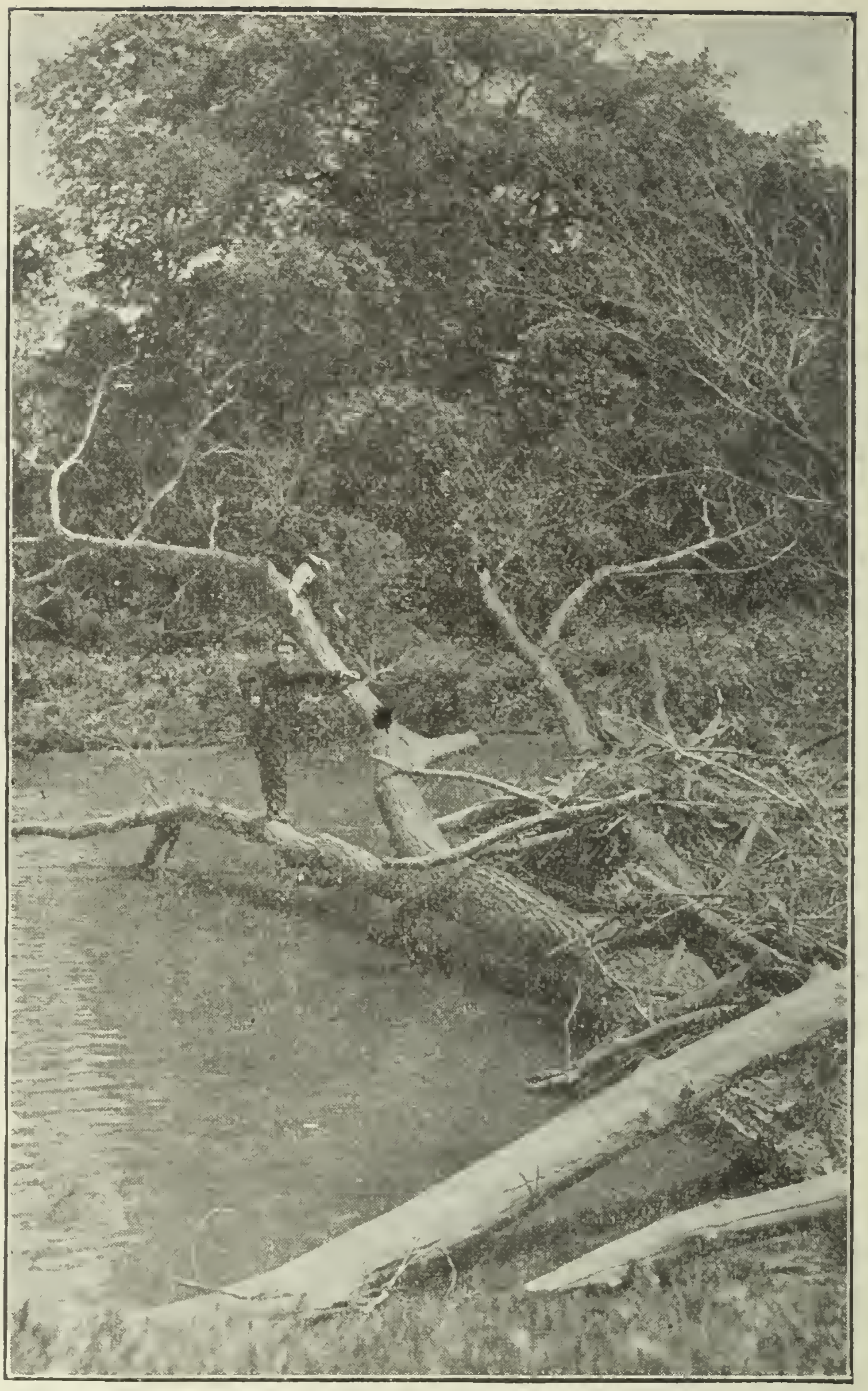
Goddard's Dam, at Freeport, has a crest length of 119 feet and develops a head of about 4.2 feet at medium low water stage. It is owned and operated by the Freeport Railway and Light Company in producing electric power for traction and lighting purposes.

Brown's Dam, about 10 miles below Freeport, has a crest length of 175 feet with available head of about 4.2 feet at medium low water and is operated by the Pecatonica River Power Company for electric traction and lighting purposes.

Orangeville Dam, at Orangeville on Richland Creek, Charles W. Bennett, owner, furnishes power for a feed mill and an electric lighting system.

The Rivers and Lakes Commission has held public hearings and passed on matters relative to back water effects of Goddard's Dam and Brown's Dam in the cases of *Robert Ilgen et al.* v. *Freeport Railway and Light Company et al.,* (Docket No. 12). Case of *C. C. Nolb* v. *Chas. W. Bennett,* account of back water. Dam at Orangeville (Docket No. 75).

PLATE I.



A. Nucleus of a Natural Dam.

B. Illustration of Bank Erosion.

The following is a list of dams in the Illinois portion of the drainage area showing the owners, location, and uses. In addition to this list permits have been granted by the state of Wisconsin for twenty dams in that state.

LIST OF EXISTING DAMS ON PECATONICA RIVER AND ITS TRIBUTARIES IN ILLINOIS.

Local name.	Owner.	Location.	Uses.	Stream.
Pecatonica Dam..	....	Sec. 20, T. 27 N., R. 10 E.	Grist mill not in use............	Pecatonica.
Brown's Dam......	Freeport Light & Power Co..	Sec. 1, T. 26 N., R. 8 W.	Electric light and power....	Pecatonica.
Goddard's Dam...	Freeport Light & Power Co..	Sec. 30, T. 27 N., R. 8 W.	Electric light and power....	Pecatonica.
Fisher's Dam......	S. K. Fisher....	Sec. 12, T. 28 N., R. 6 E.	Not in use......	Pecatonica.
Orangeville Dam..	C. F. Bennett...	Sec. 36, T. 26 N., R. 7 E.	Electric light and feed mill.	Richland Creek.
Yellow Creek Dam	....	Sec. 14, T. 26 N., R. 6 E.	Not in use......	Yellow Creek.
Buena Vista Dam.	....	Sec. 15, T. 23 N., R. 7 E.	Not in use......	Richland Creek.
Scioto Mills Dam..	....	Sec. 10, T. 27 N., R. 7 E.	Not in use......	Richland Creek.
Reader's Dam.....	....	Sec. 23, T. 27 N., R. 9 E.	Not in use......	Rock Run.
Polsbury Mill Dam	....	Sec. 35, T. 28 N., R. 9 E.	Not in use......	Rock Run.
Davis Mills Dam..	....	Sec. 27, T. 28 N., R. 9 E.	Not in use......	Rock Run.
Mill Pond Dam....	....	Sec. 15, T. 28 N., R. 9 E.	Not in use......	Rock Run.

STREAM FLOW.

GENERAL CONDITIONS OF FLOW.

The surface of the Pecatonica drainage basin at the headwaters in Wisconsin is steep and hilly, and the slope of the channel relatively great. In Illinois, however, the valley flattens out the slope of the channel gradually lessens, and the river winds back and forth across the valley, often doubling back on itself so as to form sharp oxbows. The average fall of the river in Wisconsin is more than 6 feet per mile, whereas in Illinois it is only a little over half a foot per mile. The width of the channel ranges from 100 to 200 feet. The banks are low or of medium height, and are, in most places, fringed with a heavy growth of timber. The valley contains no large lakes or swamps which might serve as natural reservoirs for storing and retarding the flood waters.

The form of the channel in the bottom lands is subject to continuous change due largely to erosion of the banks. This change is generally slow but in some seasons it amounts to several feet. Occasionally a tree, whose roots have been undermined by the water, falls into the river and forms the nucleus of a natural dam that causes the river during high stages to cut an entirely new channel for some distance. Plate I shows something of the cause and effect of such action, and Plate II shows two distinct natural channel diversions that were doubtless the result of similar action.

The average annual precipitation in the valley is about 33 inches, the larger part usually falling in the spring and summer months. The water of a heavy rainfall in the steep upper regions of the drainage basin reaches the flat bottom lands so quickly that it overfills the crooked and somewhat snag-obstructed channel and spreads out over the adjacent low lands, often covering the entire valley.

STREAM GAGING DATA.

Gaging stations have been maintained on the river and records of flow collected since 1914 by the Railroad Commission of Wisconsin

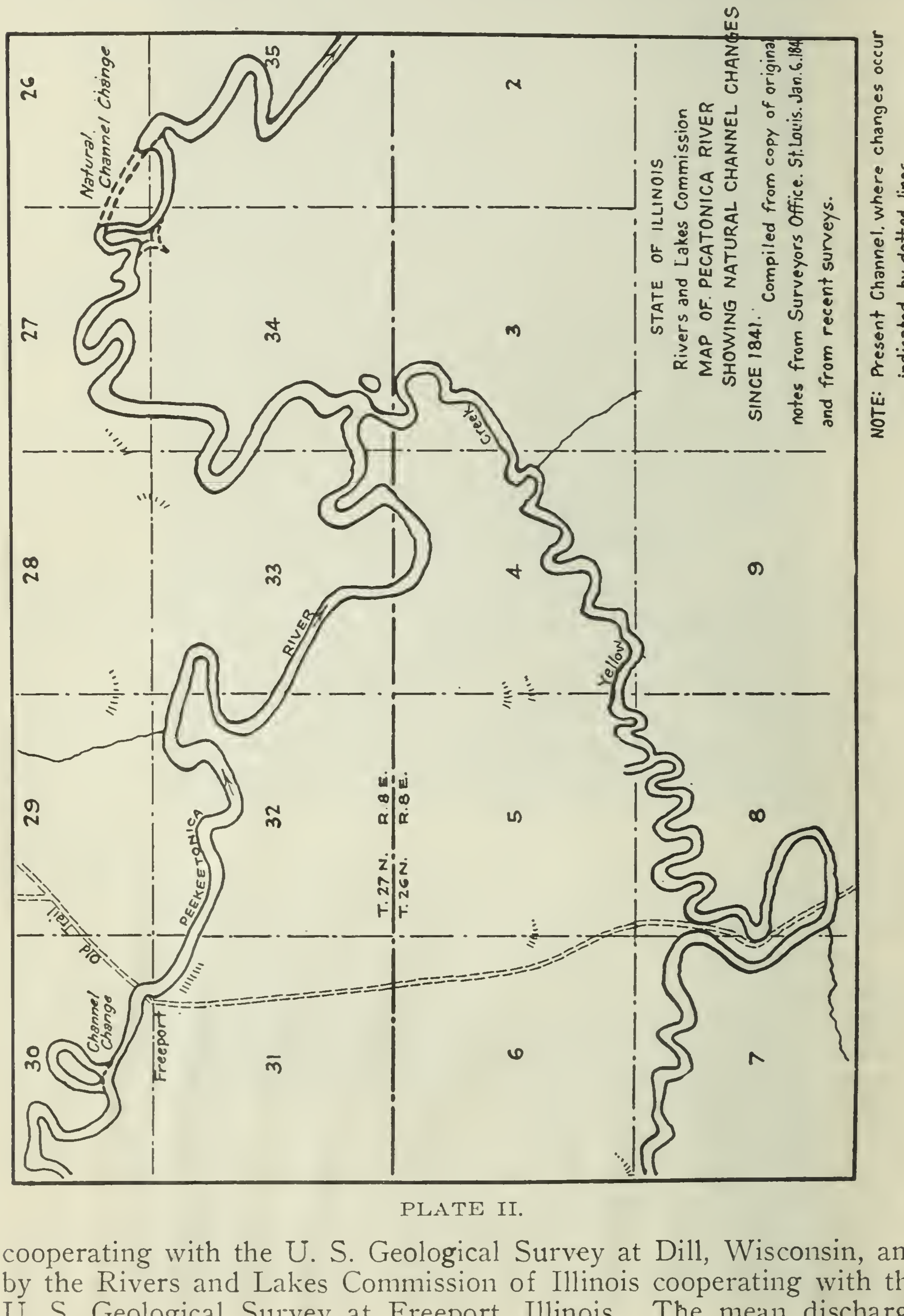


PLATE II.

cooperating with the U. S. Geological Survey at Dill, Wisconsin, and by the Rivers and Lakes Commission of Illinois cooperating with the U. S. Geological Survey at Freeport, Illinois. The mean discharge at these stations is determined for each day by applying the mean of two observed gage heights to a rating curve which shows the relation between gage height and discharge and which is based on discharge measurements made with a current meter. The records of mean daily gage height and discharge are given in the water supply papers of the U. S. Geological Survey, and will also be published at an early date in a report on the water resources of Illinois by the Rivers and Lakes Commission. Summaries of these data follow. In the data presented the following definition of terms is used:

"Second-feet" is an abbreviation for "cubic feet per second." A second-foot is the rate of discharge of water flowing in a channel of rectangular cross-section 1 foot wide and 1 foot deep at an average velocity of 1 foot per second.

MONTHLY DISCHARGE OF PECATONICA RIVER AT DILL, WIS., FOR THE YEARS ENDING SEPTEMBER, 30, 1914-1916.

(Drainage area, 959 square miles.)

Month.	Discharge in second-feet.				Run-off.	Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	
1914						
October	....	....	....	....	....	....
November	....	....	....	....	....	....
December	....	....	....	....	....	....
January	....	....	....	....	....	....
February	....	....	308	0.321	0.24	C
March	....	....	681	.710	.82	C
April	803	411	515	.537	.60	A
May	1,290	355	575	.600	.69	B
June	1,340	399	613	.639	.72	A
July	879	336	430	.449	.52	A
August	651	300	352	.367	.42	A
September	4,110	327	839	.875	.98	B
1914–15						
October	735	376	461	.481	.55	A
November	425	....	380	.396	.44	C
December	....	....	315	.328	.38	D
January	....	....	266	.277	.32	D
February	5,460	....	1,630	1.70	1.77	D
March	1,360	556	840	.876	1.01	B
April	556	400	493	.514	.57	A
May	1,240	400	576	.601	.69	A
June	2,060	476	777	.810	.90	A
July	1,320	450	585	.610	.70	A
August	1,680	400	631	.658	.76	A
September	6,590	400	2,050	2.14	2.39	B
The year	6,590	....	741	.773	10.48	....
1915–16						
October	1,480	625	877	.915	1.05	A
November	1,320	556	679	.708	.79	A
December	661	476	538	.561	.65	C
January	5,180	489	1,780	1.86	2.14	D
February	2,510	528	1,040	1.08	1.16	D
March	a13,100	400	1,960	2.04	2.35	C
April	1,160	537	692	.722	.81	A
May	1,200	511	651	.679	.78	A
June	1,880	498	922	.961	1.07	B
July	1,320	414	521	.543	.63	B
August	462	314	375	.391	.45	B
September	1,970	356	552	.576	.64	B
The year	13,100	314	883	.921	12.52	....

a Crest stage.

MONTHLY DISCHARGE OF PECATONICA RIVER AT FREEPORT, ILL., FOR THE YEARS ENDING SEPTEMBER 30, 1915-1916.

(Drainage area, 1,330 square miles.)

Month.	Discharge in second-feet.				Run-off.	Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	
1914-15						
October	942	469	590	0.444	0.51	A
November	555	341	477	.359	.40	A
December	....	322	443	.333	.38	B
January	....	....	450	.338	.39	D
February	8,520	....	3,320	2.50	2.60	D
March	6,310	824	1,410	1.06	1.22	B
April	801	519	667	.502	.56	A
May	2,100	502	801	.602	.69	A
June	2,670	672	1,140	.857	.96	A
July	1,710	632	963	.724	.83	A
August	2,880	612	996	.749	.86	A
September	6,310	555	2,630	1.98	2.21	B
The year	8,520	322	1,140	.857	11.61	....
1915-16						
October	4,270	894	1,300	.977	1.13	A
November	2,020	757	981	.738	.82	A
December	1,020	714	813	.611	.70	B
January	6,310	593	2,480	1.86	2.14	D
February	3,830	714	1,500	1.13	1.22	D
March	17,000	593	2,910	2.19	2.52	B
April	7,770	779	1,270	.955	1.07	A
May	1,530	757	1,050	.789	.91	A
June	3,120	894	1,600	1.20	1.34	A
July	1,710	537	874	.657	.76	A
August	1,090	423	530	.398	.46	A
September	2,520	453	844	.635	.71	A
The year	17,000	423	1,350	1.02	13.78	....

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained on the assumption that the run-off is distributed uniformly both as regards time and area.

"Run-off, depth in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in inches of depth.

The information given in the column headed "Accuracy" in the monthly discharge table is applicable to the monthly mean only and not to the estimate of maximum and minimum discharge nor to that for any one day. It is based on the accuracy of the rating curve, the probable reliability of the gage reader, the number of gage readings per day, the range of the fluctuations in stage, and knowledge of local conditions. In this column A indicates that the mean monthly flow is probably accurate within 5 per cent; B, within 10 per cent; C, within 15 per cent; D, within 25 per cent. Special conditions are covered by foot notes.

STUDY OF DURATION CURVES AND DISCUSSION OF FLOW.

The duration curves, FIGURES 1 and 2 for the flow at Freeport show the number of days and percentage of time in each year that the flow equalled or exceeded any given amount. For example, to find the number of days in 1916 that the flow was equal to 4,000 cubic feet per second, follow the horizontal line representing that quantity to the point where it intersects the curve and then drop vertically downward to the scale of days, which shows 17 days. Subtracting 17

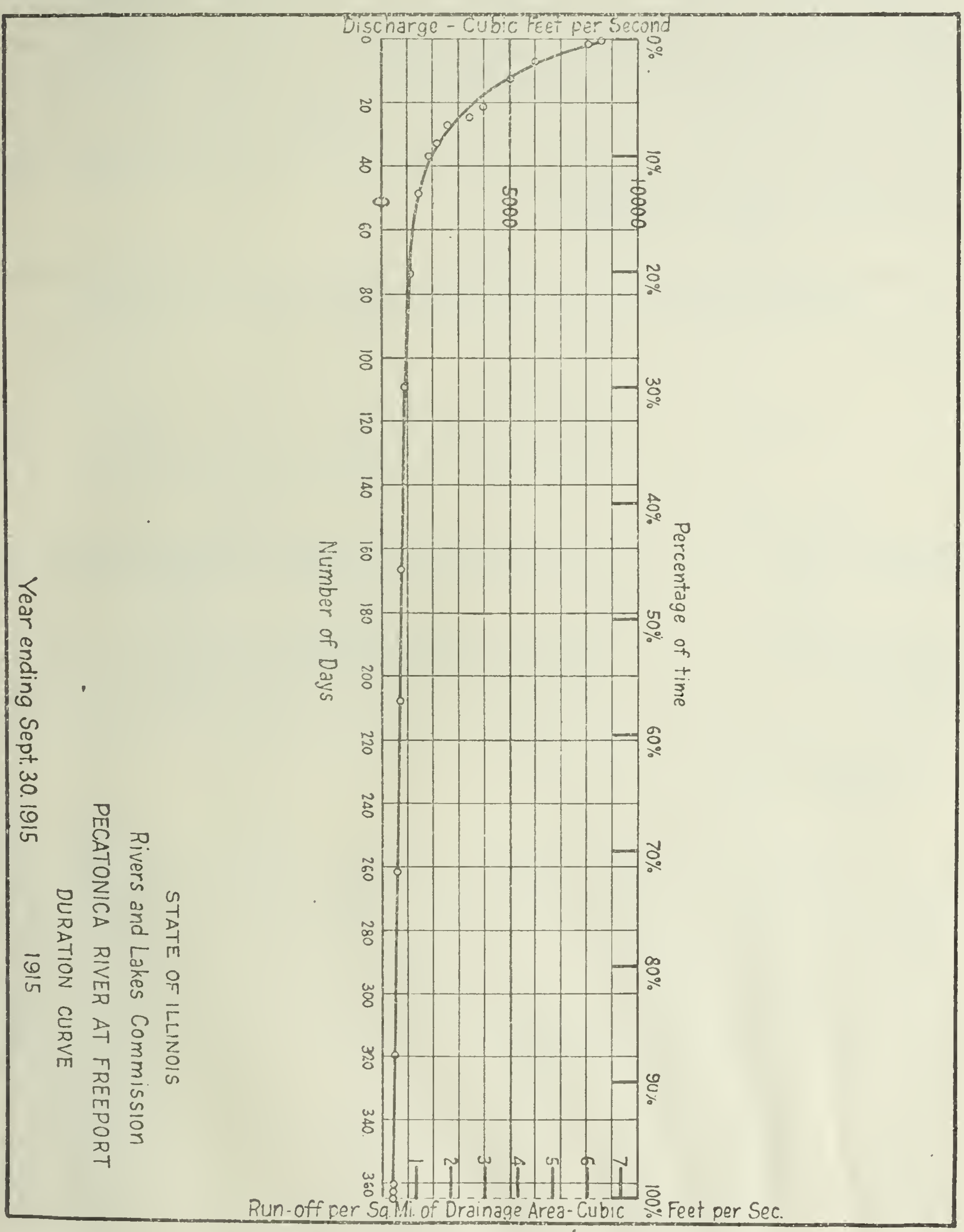


FIGURE 1.

from 366 gives 349 as the number of days for which the flow was less than 4,000 cubic feet per second.

The terms "ordinary flow" and "normal flow" are usually taken to mean the flow which is equalled 50 per cent of the time, or, in other words, the flow that is exceeded as many days in the period under consideration as it is not equalled. The duration curves show that the ordinary flow for 1915 was 660 cubic feet per second, or 0.496 cubic feet per second per square mile of drainage area; and that for 1916 was 930 cubic feet per second, or 0.699 cubic feet per second per square mile.

The "average flow" or "mean flow" of a stream is the average for all the days during the period under consideration. It is not the same as the "ordinary flow." The tables of monthly discharge show that the average flow at Freeport for 1915 was 1,140 cubic feet per second, or 0.857 cubic feet per second per square mile, and that for 1916 was 1,350 cubic feet per second, or 1.02 cubic feet per second per square mile. It will be observed that these are larger than the ordinary flow for the same periods.

PRECIPITATION, IN INCHES, AT STATIONS IN DRAINAGE BASIN OF PECATONICA RIVER DURING THE YEARS ENDING SEPTEMBER 30, 1915-1916.

Station.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	Annual.
1914-1915													
Dodgeville, Wis.	3.20	0.48	1.15	1.31	1.92	0.20	0.00	7.78	2.90	5.43	2.12	11.88	38.37
Darlington, Wis.	3.21	0.45	2.05	0.75	2.53	0.75	0.30	6.30	4.15	4.35	4.00	10.85	39.69
Dakota, Ill.	2.00	0.24	1.99	1.39	1.04	0.11	0.20	*a*	4.63	7.21	2.66	6.77	*b*28.24
1915-1916													
Dodgeville, Wis.	0.34	3.52	0.50	4.30	1.20	3.82	2.30	4.35	7.50	0.46	2.27	7.20	37.76
Darlington, Wis.	0.70	2.45	0.14	2.15	1.02	3.06	3.00	2.40	4.85	2.64	1.17	8.05	31.63
Dakota, Ill.	0.64	2.95	0.18	3.89	0.81	2.44	....	....	....	....	....	....	....
Freeport, Ill.	....	....	....	....	....	....	....	5.30	7.88	1.60	4.60	9.05	*c*39.34

a No record.
b 11 Months.
c 11 months at Dakota and Freeport.

Although the total precipitation during each year was about the same it will be noted that both the ordinary and average flow were considerably less in 1915 than in 1916. This was due probably to the difference in the distribution of the precipitation throughout the years. The precipitation from July to September, inclusive, when the quantity evaporated and used by plants would be the greatest, was a larger percentage of the total precipitation for the year in 1915 than in 1916. Also, the heavier rainfall during the summer of 1915 increased the amount of water held as ground storage and afterward gradually released to augment the flow during the following autumn, thereby increasing the flow for 1916. Further, in 1916, the precipitation from January to April inclusive, when the percentage of run-off would be relatively large, was greater than for the same period in 1915.

It is difficult to estimate from the records of only two years how these ordinary and average flows would compare with those determined from records of a much longer period. The average precipitation in the drainage basin for each year was about 37 inches, whereas the normal annual precipitation for this region is only about 33 inches. Owing, however, to the conditions favorable to relatively small run-off that existed during 1915, as described above, the results for that year are probably nearer the average that might be expected from a long period.

It is interesting to note that the average flow per square mile of drainage area was greater at Dill than at Freeport during both years, the average flow at Dill having been 0.773 and 0.991 cubic feet per

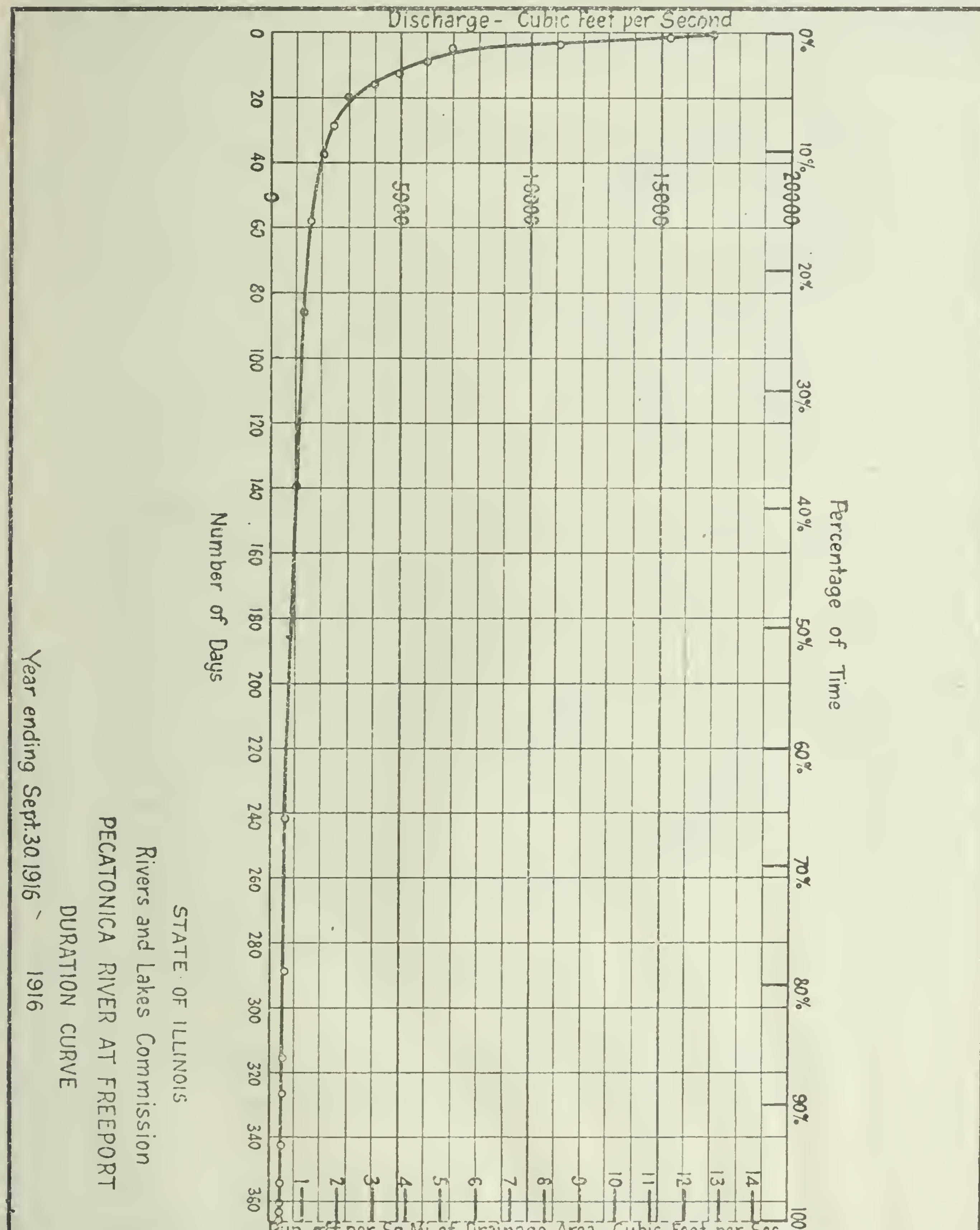
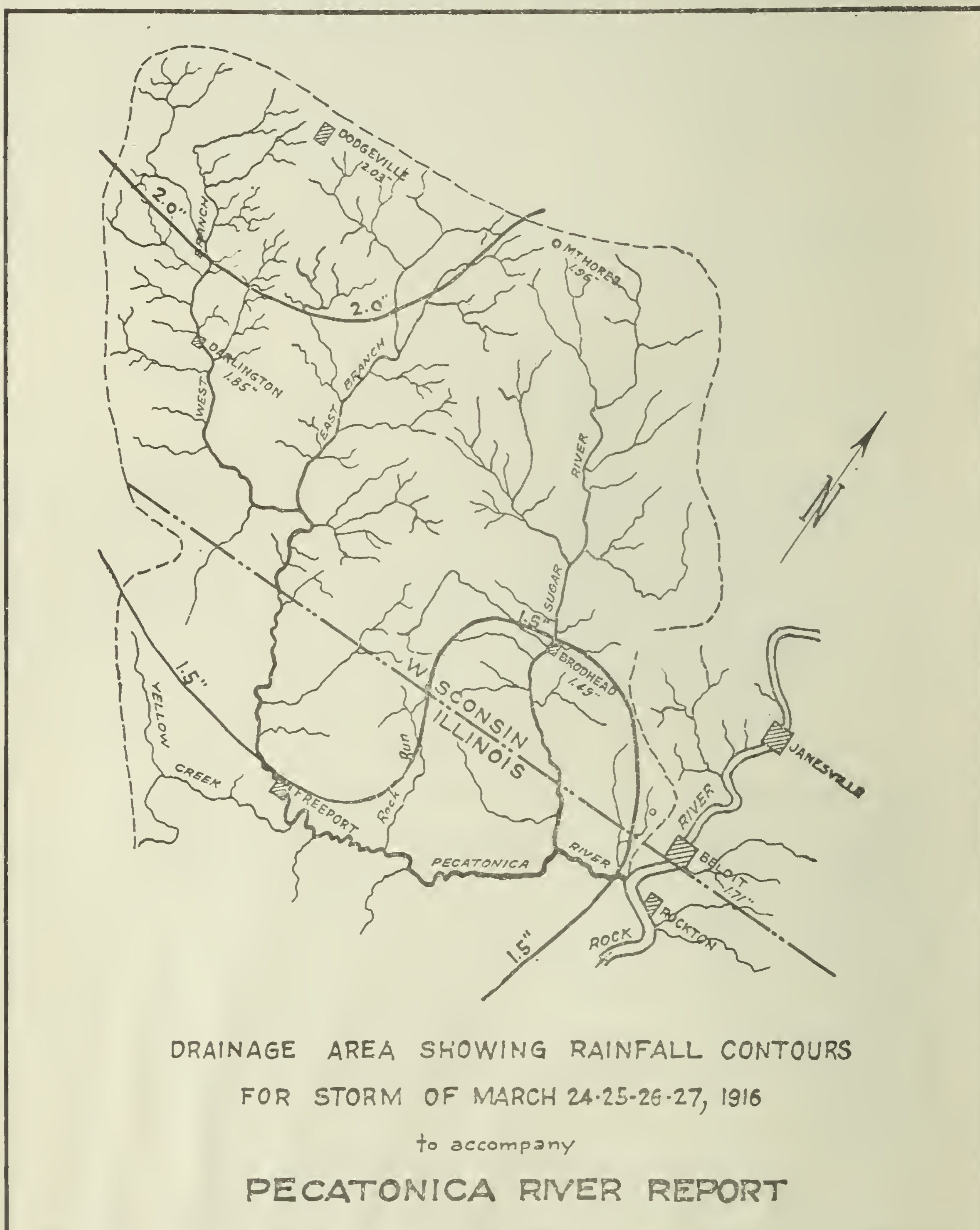


FIGURE 2.

second per square mile in 1915 and 1916 respectively, and that at Freeport only 0.564 and 0.797 cubic feet per second per square mile during the same periods. This probably was due largely to the fact that the average slope of the drainage basin above Dill is greater than that above Freeport. Other things being equal, the run-off from steep slopes is greater than that from moderate or flat slopes.

PAST AND PROBABLE FUTURE FLOODS.

As conditions that exist in the region of the headwaters favor quick run-off, floods on the river are caused rather frequently by the



DRAINAGE AREA SHOWING RAINFALL CONTOURS
FOR STORM OF MARCH 24-25-26-27, 1916
to accompany
PECATONICA RIVER REPORT

PLATE III.

heavier storms, and usually the banks in Illinois are overflowed several times each year. As a rule spring floods are the heaviest and, especially when accompanied by ice jams, cause considerable damage in the city of Freeport. Water passing over the east bank above the city flows through the section known as East Freeport, inundating large areas, flooding the cellars and ground floors of residences, destroying goods and furniture and putting out of service the sewerage system. At the factories, some of which employ more than 2,000 men, the damage to property and the loss in time and wages are great. Traffic on most of the railroads is prevented by the washing out or submerging of the tracks, and even vehicle traffic is made impossible. The average annual monetary loss is estimated by Mr. C. S. Hepner, city engineer, Freeport, at $50,000.

The summer floods, although usually not so large as those of the spring, inflict much damage on the farm lands and often destroy whole fields of corn and wheat.

Since the gaging station at Freeport was established, in September, 1914, many floods have occurred. On September 16, 1914, the river reached a stage of 18.4 feet on the gage, flooded East Freeport and caused much damage to crops on the low farm lands. In 1915 it reached a stage of 17.1 feet February 28, 16.1 feet September 17-18, and 15.8 feet September 28. In 1916 it reached a stage of 16.5 feet January 22, 16.8 feet January 28, 14.1 feet February 23, and 19.4 feet March 28.

The storm causing the flood of February, 1916, left the drainage basin with an impervious coating of ice and frost which, on March 22, was covered with a blanket of snow equivalent to a rain of about 0.8 inch. The temperature began to rise March 24, and in the next three days there was a rainfall, as shown in Plate III, averaging about 1.75 inches on the drainage basin. Although the precipitation during this period was not exceptionally heavy, the run-off was very rapid, owing to the impervious condition of the ground, and the flood was the largest within the memory of the oldest residents of the valley. The water began to rise rapidly at Freeport March 25, reaching the maximum stage of 19.4 feet by the morning of March 28 and continuing at that stage until night. By the next morning the water had dropped to 19.2 feet on the gage and it continued to fall slowly. At the maximum stage of 19.4 feet on March 28 the discharge, or flow, in the regular channel of the river at the Stephenson Street bridge was measured by H. C. Beckman, junior engineer, U. S. Geological Survey, by means of a current meter and found to be 14,000 cubic feet per second. The amount of the overflow through East Freeport was determined by multiplying the mean velocity, estimated from the velocity of driftwood, by the cross-sectional area of the overflow channel determined by leveling after the water had subsided. This method gave a flow of 3,000 cubic feet per second. The total discharge at this maximum stage was thus determined to be 17,000 cubic feet per second, or a run-off averaging about 13 cubic feet per second per square mile from the 1,330 square miles of drainage area above Freeport. The details of time and magnitude of this flood are shown graphically in Plate IV.

As this flood came before the crops were planted the damage sustained by the farming interests was not great. In the city of Freeport, however, it was very large. Traffic into the city was stopped on most of the railroads for several days. The electric light plant and sewerage system were put out of service. The water flowing through East Freeport washed out several sections of railroad embankments, stopped the operation of and damaged considerable property at the factories,

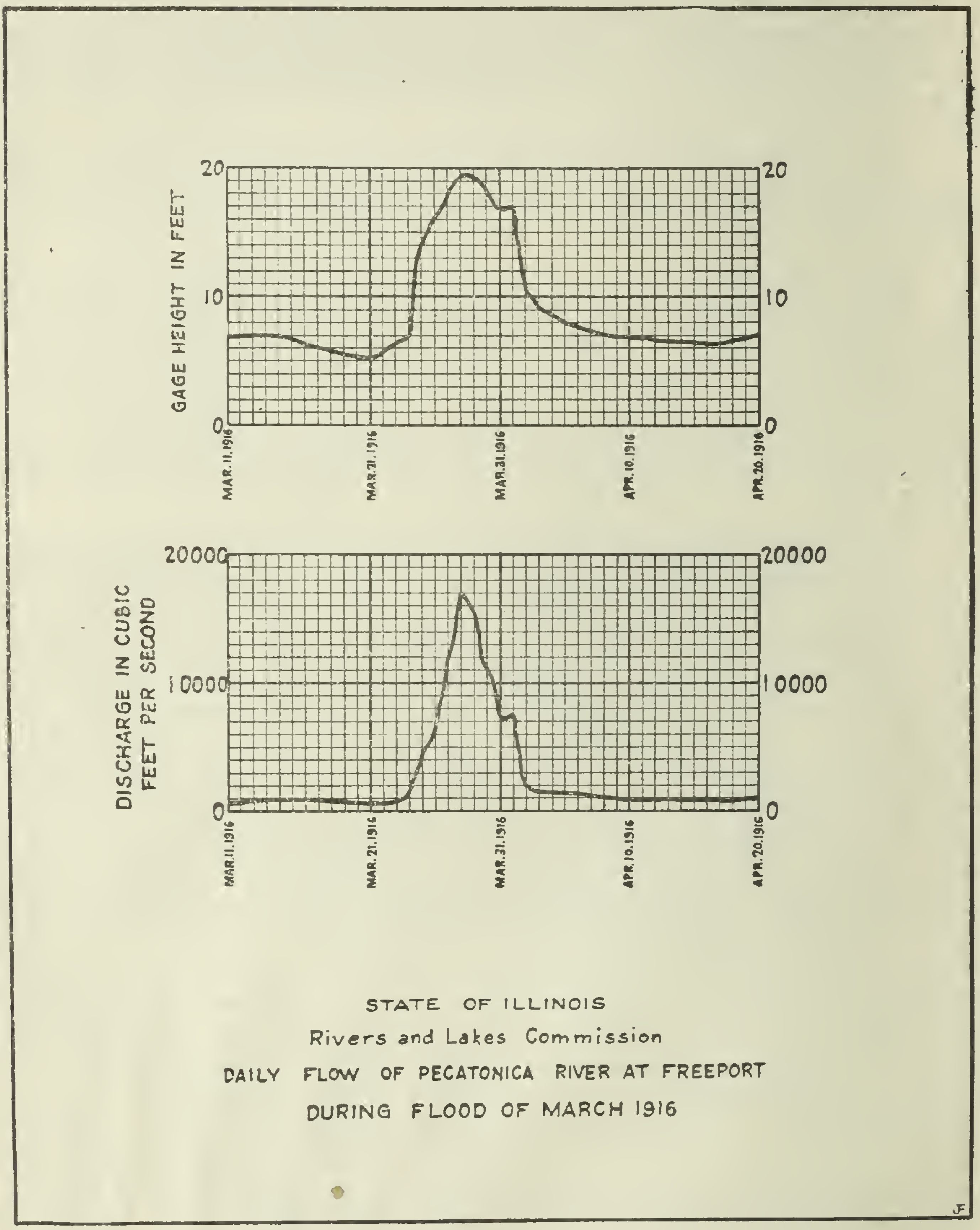


PLATE IV.

and did much damage by flooding basements and first floors of residences. Speaking of this flood Mr. C. S. Hepner, city engineer, Freeport, Ill., says that "$100,000 is a fair estimate of the direct monetary loss. The indirect loss due to depreciation of property values, reduction of rental rates, and retarding of the development of this section of the city certainly totals an equal amount."

As the flood of March, 1916, on this river was the greatest within the last fifty years, or more, it may be regarded by some as the largest possible. A study of the factors causing floods and the extent to which these factors acted in causing this particular flood indicates that this opinion is not well founded. Of the principal factors controlling run-off on any particular drainage basin, all are fixed and invariable

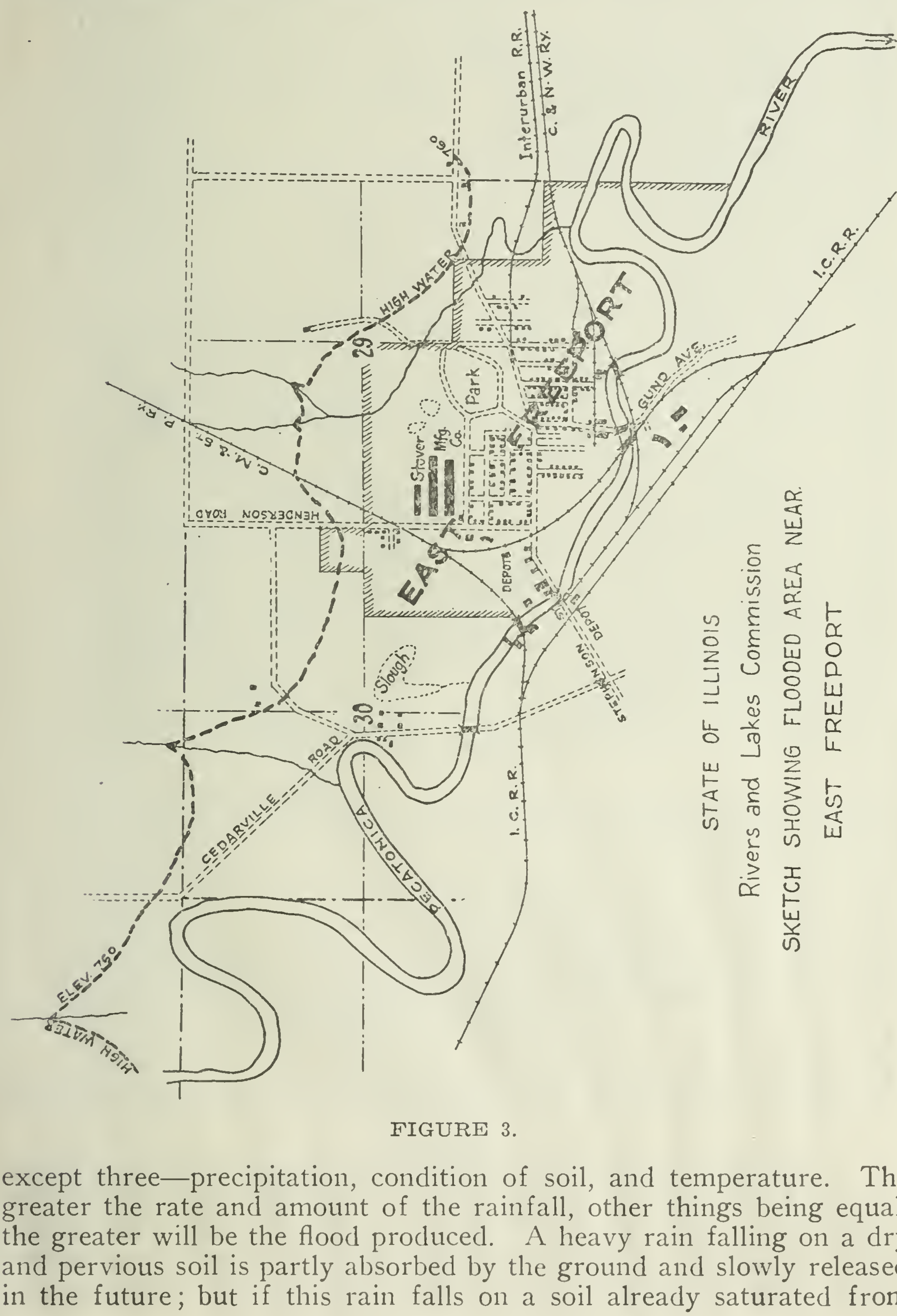


FIGURE 3.

except three—precipitation, condition of soil, and temperature. The greater the rate and amount of the rainfall, other things being equal, the greater will be the flood produced. A heavy rain falling on a dry and pervious soil is partly absorbed by the ground and slowly released in the future; but if this rain falls on a soil already saturated from previous rains, or melted snows, or on a soil made impervious by frost and ice, the run-off will be much greater, and if the rain falls when considerable snow is melting, the run-off is further augmented. The heaviest floods occur when the most favorable condition of all these factors are combined.

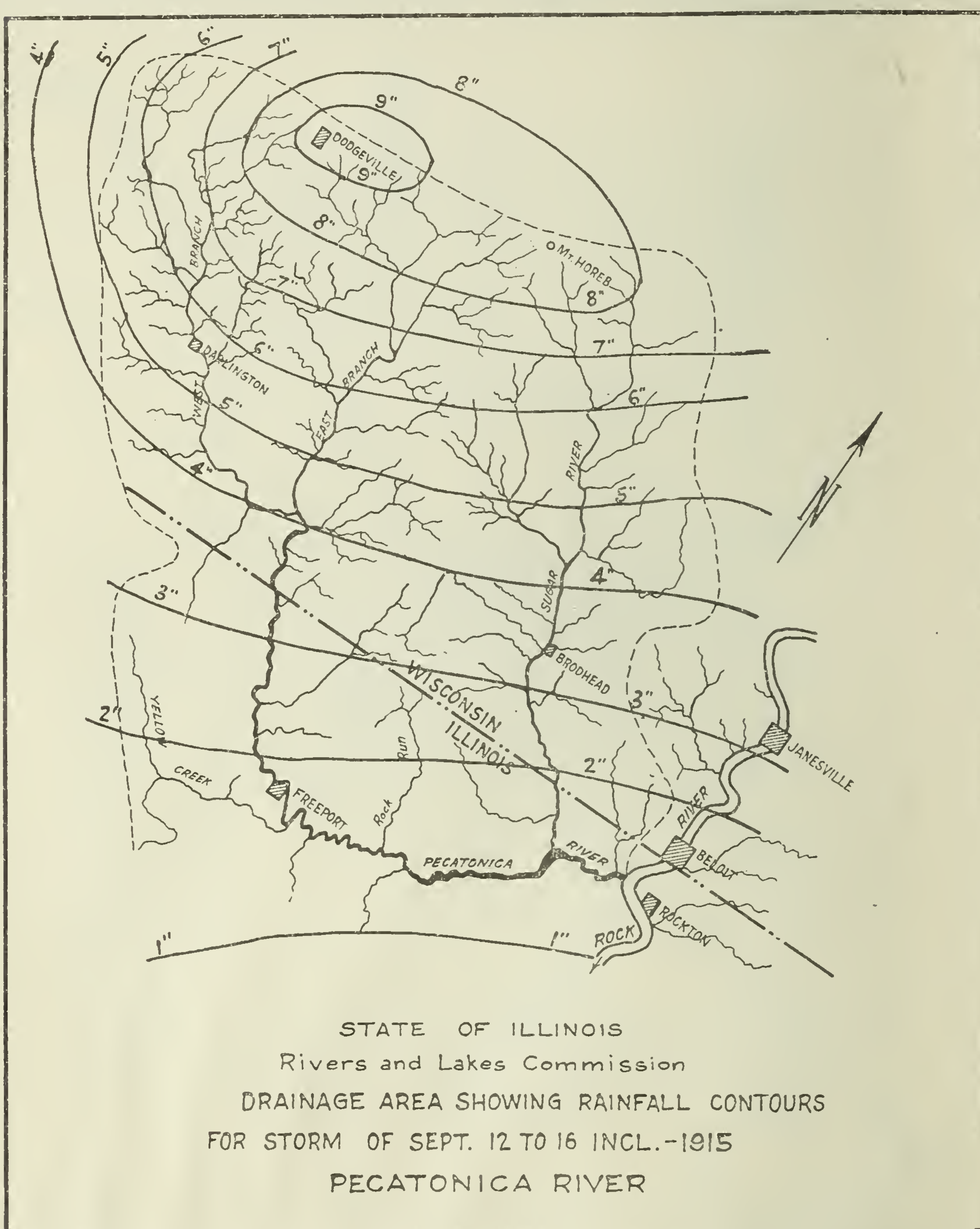


PLATE V.

As already indicated, the rainfall preceding the flood of March, 1916, was not large, but the conditions of temperature and soil were ideal for quick run-off, as the ground was sealed with frost and ice, thus preventing absorption of water, and the temperature increased just in time to add snow water to that resulting from the rain.

During September 12-16, 1915, one of the heaviest storms ever recorded in Southern Wisconsin swept across that region. The average rainfall, as shown in Plate V on the drainage area above Freeport was over 5 inches, the maximum having been 9 inches in the vicinity of Dodgeville, Wis. This storm, however, came at a time when the ground was fairly dry, and although the rainfall was about three times as large as that of March, 1916, the maximum discharge of the river at Freeport was less than half as large.

The maximum discharge per square mile of area drained is never as great under the same conditions from a large drainage basin as from a small one. This is due to the fact that in the larger drainage basin a greater part of the water falling in the lower regions of the basin can be carried away before the water from the upper regions arrives. The drainage area of Sugar River, a tributary of the Pecatonica, above Brodhead, Wis., is 529 square miles whereas that for Pecatonica River above Freeport is 1,330 square miles. The average slope of the river above Brodhead is also greater than that above Freeport, so that the rate of run-off at Brodhead would be greater. In the storm of September 12–16, 1915, the average rainfall above Brodhead was nearly 6 inches, yet the maximum discharge was only about 16 cubic feet per second, or a square mile rate of only about 25 per cent greater than that of the Pecatonica River during March, 1916.

Much heavier storms than either the one of September, 1915, or March, 1916, have occurred in the Upper Mississippi Valley in recent years. During July 23–24, 1912, there fell in about 24 hours at Merrill, Wis., a rain of 11.25 inches; 10 inches fell on an area of 100 square miles, and 6 inches on an area of 1,650 square miles. According to Mr. C. B. Stewart, consulting engineer, Madison, Wis., the average rainfall on the 700 square miles of area draining into the Wisconsin River between Merrill and Tomahawk was 7.7 inches, and the maximum run-off from this area about 65 cubic feet per second per square mile.

During March 23–27, 1913, a heavy storm occurred in the vicinity of Dayton, Ohio. The average rainfall in the drainage basin of Miami River above Miami, near the mouth, was about 9.5 inches. The maximum run-off from this area of 3,937 square miles was 98 cubic feet per second per square mile. [1] The following table gives the rainfall on areas of 1,500 square miles, or a little greater than the drainage area of Pecatonica River at Freeport, for nine of the greatest recorded storms in the Upper Mississippi Valley:

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[1] From report of Chief Engineer, Arthur E. Morgan, Miami Conservancy District.

DEPTH IN INCHES OF THE EATEST AVERAGE RAINFALL ON AREAS OF 1,500 SQUARE MILES DURING NINE GREATEST STORMS THAT HAVE OCCURRED IN THE UPPER MISSISSIPPI VALLEY.

Storm.	Center.	Greatest 24-hour rainfall.	Greatest 48-hour rainfall.	Greatest 72-hour rainfall.
1889, May 31–June 1	Pennsylvania	7.3	8.6	....
1900, July 14–16	Iowa	6.5	10.1	10.9
1903, August 26–28	Iowa	9.5	10.2	....
1905, June 9–10	Iowa	9.2	....	....
1909, July 5–8	Kansas	6.5	7.2	9.4
1909, July 19–22	Michigan	7.0	7.9	8.3
1910, October 4–6	Illinois	6.2	9.9	12.4
1913, March 23–27	Ohio	6.3	8.3	9.2
1915, August 17–20	Arkansas	6.5	9.4	12.

A comparison of the storm of March, 1916, with those cited for Merrill, Dayton and the ones listed in the above table makes it obvious that the flood of March, 1916, is by no means the largest that might occur on Pecatonica River. Had a storm as heavy as any of those cited above occurred in the drainage basin of Pecatonica River under the conditions prevailing in March, 1916, it is safe to estimate that the maximum flood flow would have been several times as great as it was, and the maximum stage reached would have been several feet higher. Even if a storm as heavy as those were to occur under ordinary summer conditions the flood of March, 1916, would probably be exceeded.

Several factors, however, tend decidedly to reduce the probability of such an occurrence. First, it is very improbable that the area of the most intense rainfall of any storm will cover the whole of any particular drainage area as large as that of Pecatonica River above Freeport. Second, it is extremely improbable that a storm as heavy as those enumerated, which occur at any particular place on an average only once in a century or more, will ever occur under conditions as favorable to quick run-off as those which existed in the Pecatonica Valley during the flood of March, 1916. On the other hand, it should be borne in mind that although the probability of such occurrence is very small, it is entirely within the realm of possibility and may take place in any year.

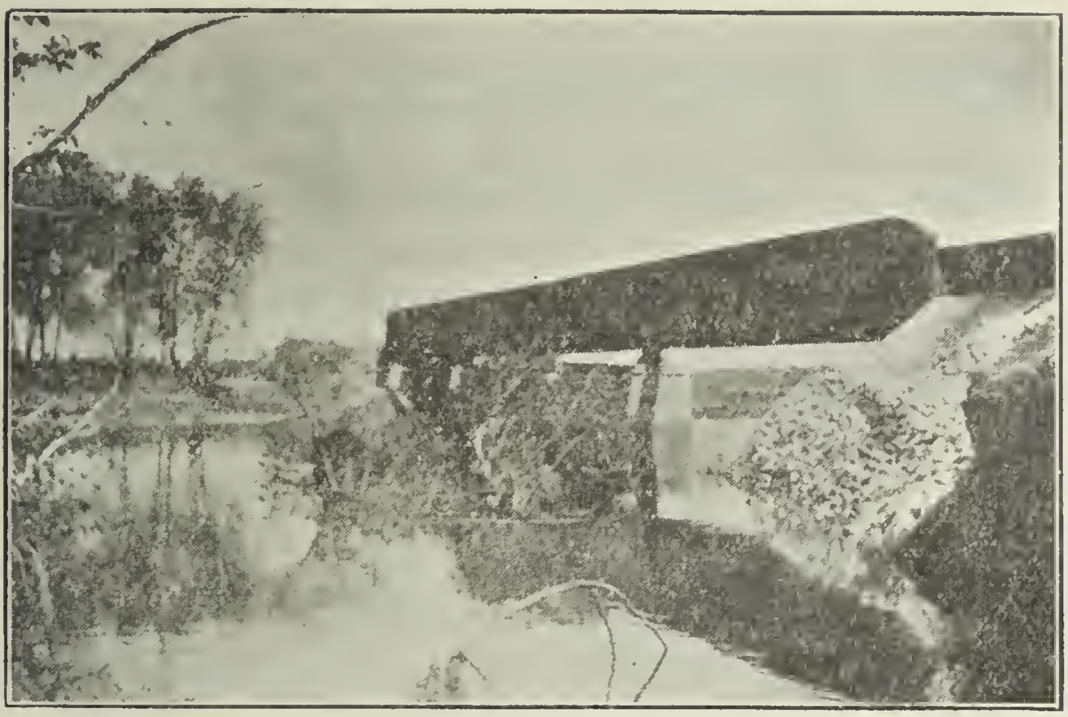
FLOOD RELIEF.

GENERAL APPLICATION.

In studying the problem of flood relief let us first consider its application to the whole section of the river which is subject to overflow. In general, the prevention of damage from floods on streams like the Pecatonica can be accomplished either by decreasing the amount of the flow by means of retarding reservoirs, decreasing the slope by channel improvement, preventing overflow by means of levees, or by some combination of these methods.

In the case of the Pecatonica, the construction of retarding reservoirs is out of the question for the topographical conditions are such that it would require an outlay estimated at more than $3,000,000 to effect a material reduction in the flood discharge by this means. The

PLATE VI.



A. Bridge, Looking Down Stream.

B. Bridge, Looking Up Stream.

C. East Approach to Bridge.
C. & N. W. Ry. Bridge and Approach at Freeport.

method of channel improvement, as applied to the whole valley, is also impracticable on account of the enormous amount of work and expense involved as compared with the benefits that would result from such a project. These methods have been studied somewhat in detail in connection with the survey, but it seems unnecessary to further develop them in this report. The results, however, indicate that local relief must be obtained by the application of local measures where the cost of such measures is commensurate with the value of the protection secured.

The agricultural bottom lands could be protected against overflow by the construction of levees, but this would require that additional channel area be provided to compensate for the reduction in width of natural floodway produced by the levees and, at present, the benefits to be derived from such improvement hardly seem to warrant the expenditure that it would involve. It is possible, however, that the growing demands of agriculture and the gradual silting up of the river bed will make it desirable to adopt such measures for the protection and reclamation of certain areas at some future time.

THE PROBLEM AT FREEPORT.

The flood conditions at Freeport, as previously described in the chapter on "Past and Probable Future Floods," are much more acute than at any other point in the valley and have become a serious menace to the industrial growth and welfare of the city. These conditions have been greatly aggravated during recent years by the encroachments of man upon the natural flood channel of the stream. Practically all the land now occupied by East Freeport was originally a part of the river's flood domain. Even the narrow confines of its medium flood channel have been invaded by bridges, manufacturing plants, dams, cinders, city refuse, and what not, until the flood waters have been forced to such heights that the low lying sections of the city have become their legitimate prey.

A profile of the water surface based on observations of the March, 1916, flood (See Fig. 4) shows a fall of 2.7 feet between Cedarville Road and a point just below the Chicago & Northwestern Railway bridge, or about 2.1 feet per mile, while the corresponding slope below this point, where the river is allowed to spread over the whole valley, was only 0.5 feet per mile.

In seeking the best method of protection for Freeport the possibilities of improving the old channel have been considered as well as the relative advantages and disadvantages of using various channel areas. It has been found that a plan contemplating the enlargement of the old channel would require such an extensive use of high retaining walls, on account of the limited width available, that its cost would greatly exceed that of an auxiliary channel. After careful and exhaustive study the following general plan is recommended as the most practical and satisfactory means of securing the desired protection.

PLAN OF PROTECTION RECOMMENDED FOR FREEPORT.

The recommended plan of flood protection contemplates the construction of an additional channel through East Freeport, beginning at a point just above Cedarville Road, thence following eastward along the center line of section 30 through the north end of Taylor Park to a point a quarter of a mile east of Henderson Road, thence in a southeasterly direction following the general course of the creek in that region to its confluence with the river. Levees to prevent

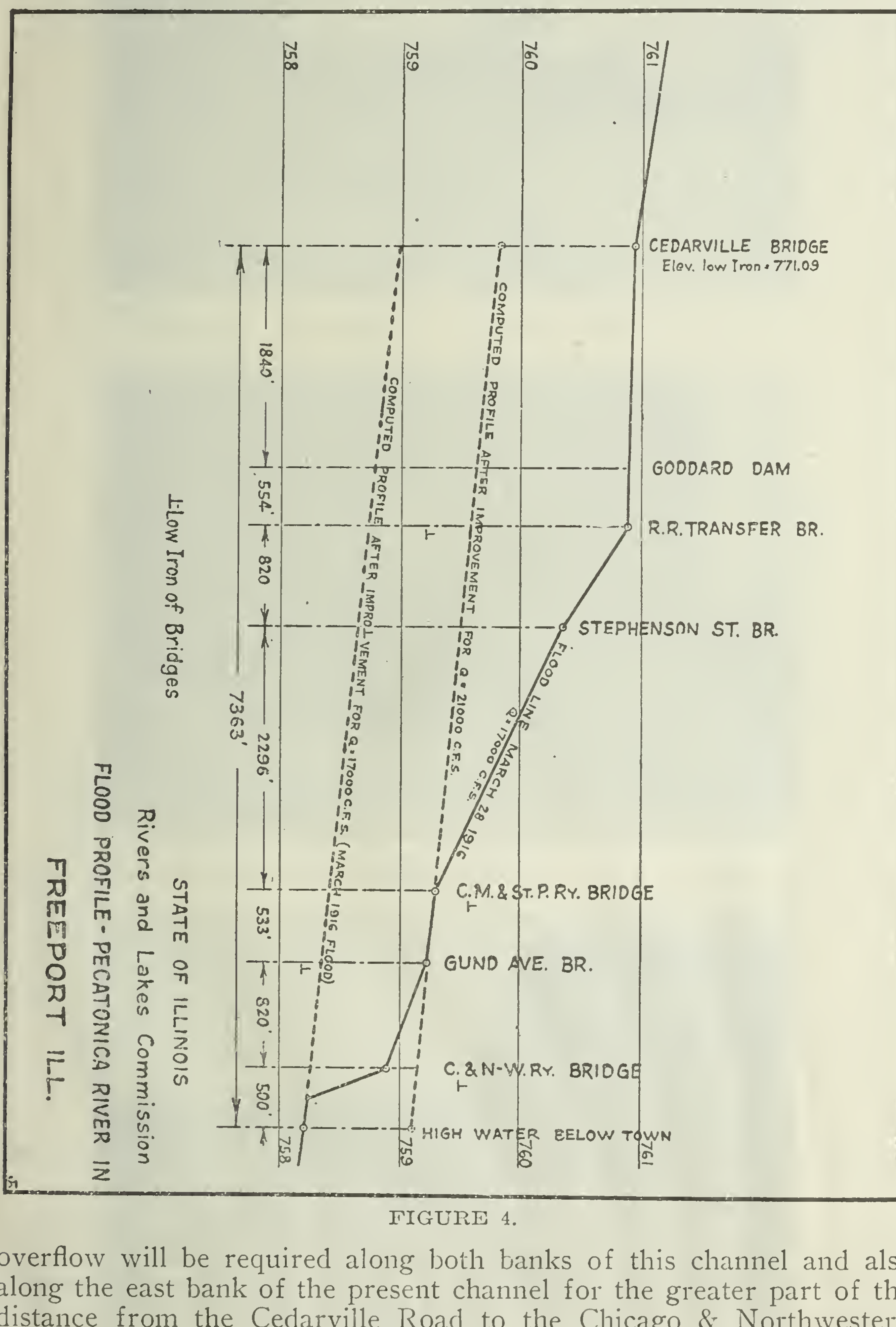


FIGURE 4.

overflow will be required along both banks of this channel and also along the east bank of the present channel for the greater part of the distance from the Cedarville Road to the Chicago & Northwestern Railway bridge below the city. In order to maintain the ordinary

PLATE VII.

A. R. R. Transfer Bridge, Looking Down Stream.

B. West End of R. R. Transfer Bridge, Looking Down Stream

C. Cinder Pile at Moline Plow Works.

stages of water and yet provide for the ready passage of flood waters down the new channel it is proposed to construct, at the upper end of this channel, an overflow dam having a spillway about 300 feet long, the crest elevation of which will be slightly higher than that of the Goddard dam. A general outline of the entire project is shown on the accompanying map, Plate X.

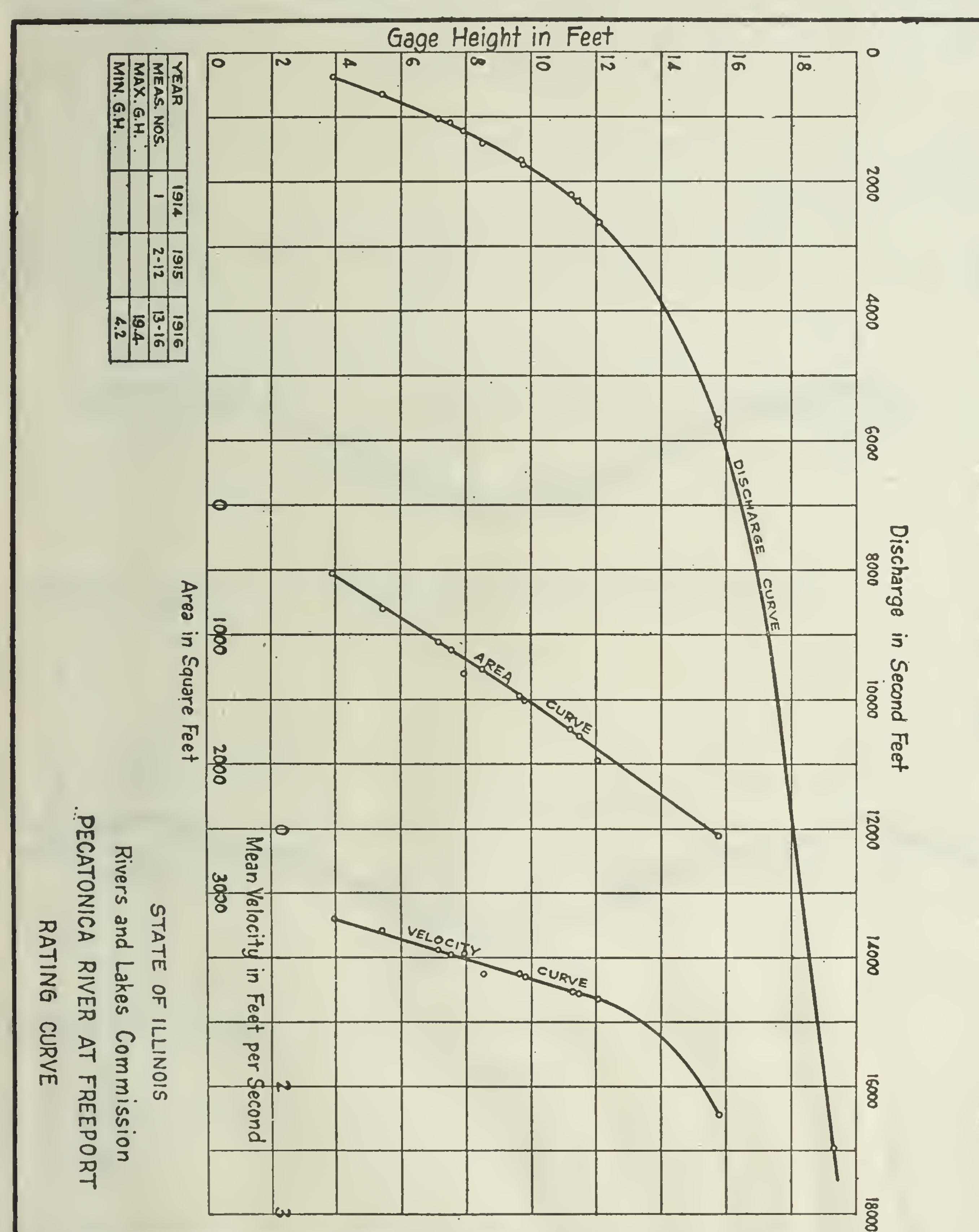


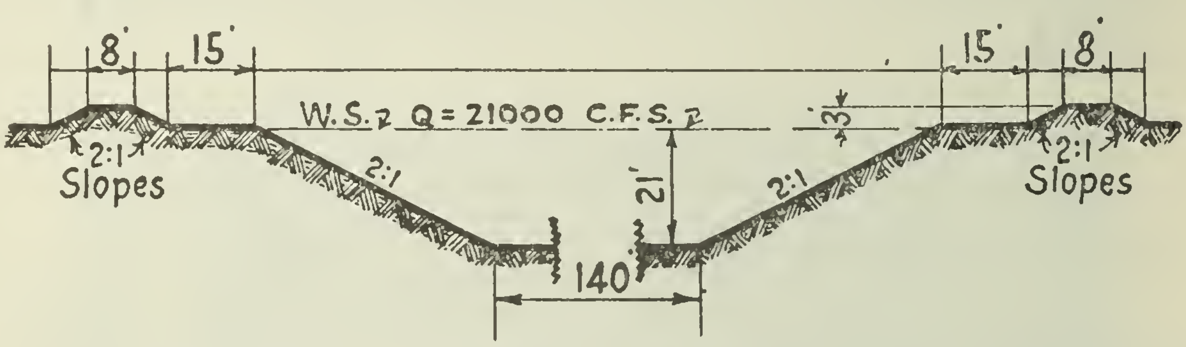
PLATE VIII.

In the chapter on "Past and Probable Future Floods" it was shown that floods considerably greater than the one of March, 1916, although somewhat improbable, may occur. The question now arises as to how great a flood shall be provided against. Protection against the heaviest possible floods would, on account of the probable infrequency of such floods and on account of physical limitations, be impracticable. After careful consideration it has been deemed advisable to base the design of the proposed improvement upon a flood discharge of 21,000 cubic feet per second, or about 25 per cent greater than that of March, 1916.

This improvement will have practically no effect on the flood stage below the city but will serve to reduce the slope through the city and confine the water to the channels provided for it.

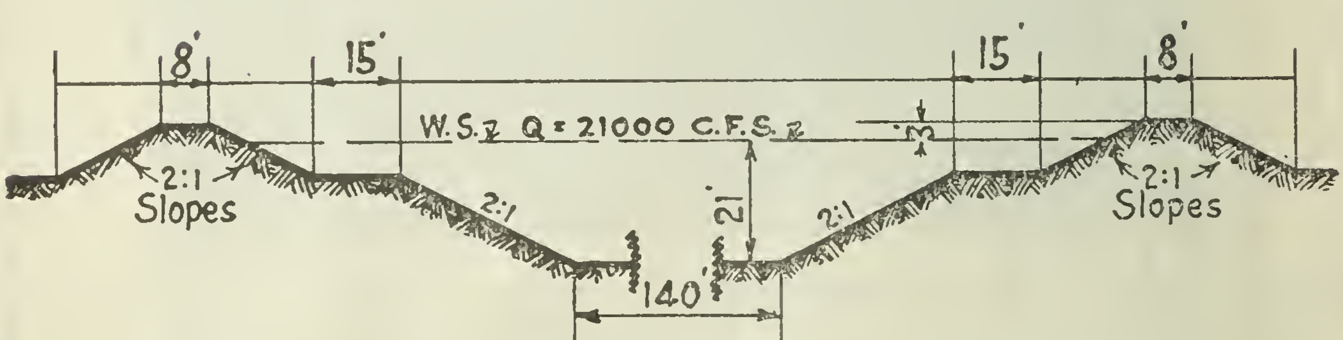
The profile (Fig. 4) shows the high water line of March, 1916, through Freeport. The surface slope below the city, owing to the greater area of overflow there, was considerably less than the slope through the city.

The high water elevation of March, 1916, below the Chicago & Northwestern Railway bridge near the lower limits of the city was 758.2 feet. From the rating curve (Plate VIII) it may be deduced



Cross-section of proposed new channel through high ground

FIGURE 5.



Cross-section of proposed new channel through low ground

FIGURE 6.

that in a flood of 21,000 cubic feet per second the surface elevation at this point would probably be raised to 759.1 feet. On the profile (Fig. 4) are shown the probable high water lines that would obtain through Freeport after the completion of the proposed improvements during floods of 17,000 (equal to the flood of March, 1916,) and 21,000 cubic feet per second. These also represent very closely, under the same conditions, the high water lines in the proposed new channel.

As stated before, the project has been designed to carry safely a flow of 21,000 cubic feet per second. In order to determine the size of additional channel necessary to accomplish this, the quantity of water that would be carried by the present channel was first computed by means of the Kutter and Chezy formulas. Taking the surface elevation below the Chicago & Northwestern Railway bridge as 759.1 feet and the slope as 0.0001, the area of the present channel in the city would be about 3,200 square feet, and the mean hydraulic radius about 15.2 feet. The value of *n* (coefficient of roughness) was computed from the flood of March, 1916, and found to be 0.045. By solving the formulas with these values it was found that the present channel would carry a flow of 7,700 cubic feet per second, leaving 13,300 cubic feet per second to be taken by the new channel.

After several trials it was found that a section, as shown in FIG. 5 for the new channel would carry the required amount. In the computations the slope, *s*, was taken as 0.0001 and the coefficient of roughness, *n*, as 0.030. The area of this section is 3,820 square feet and the mean hydraulic radius 16.3 feet. By solving the formulas with these values the mean velocity was found to be 3.46 feet per second, and the discharge very near the desired 13,300 cubic feet per second.

The bottom of the new channel will, at the lower end, be at an elevation of 738.0 feet; the slope will be 0.0001, thus making the elevation at the upper end approximately 739.0 feet. A large part of the new channel will be through rather low ground, and the required depth of 21 feet will have to be obtained by the aid of levees. FIG. 6 shows a typical cross section of the channel through the low regions.

ESTIMATED COST OF PROJECT.

Excavation—	
1,100,000 cu. yds. @ $0.18	$200,000
Bridges—	
3 railroad bridges	75,000
3 highway bridges	50,000
Dam and spillway	30,000
Right-of-way—	
For auxiliary channel, 65 acres @ $500	32,500
For levee along left bank of main river, 14 acres @ $500	7,000
Damages—	
Moving or buying 20 buildings	24,000
Miscellaneous damages	10,000
Overhead Charges—	
Engineering, administration, interest 10 per cent, etc.	42,500
Contingencies, 7 per cent	29,000
Total	$500,000

In the above estimate the price for excavation is intended to cover the cost of placing the excavated material in levees both along the new channel and the east bank of the river, and in highway embankments and other places where filling may be required.

The items for bridges are for the three railroad and three highway bridges that will have to be built across the new channel. The cost of the right-of-way is for a strip of land 300 feet wide throughout the length of the new channel, and a strip with an average width of

65 feet along the greater part of the east bank of the river through the city.

This is only an approximate estimate but is considered adequate to cover the actual cost of the undertaking.

In view of an average annual flood loss of $50,000, a total expenditure of $500,000 for protection is amply justified. The total cost is only five times the estimated direct loss sustained in the single flood of March, 1916.

CONCLUSIONS.

The following points with reference to the proposed improvement stand out for special consideration:

1. The improvement will protect the city of Freeport against a flood of 21,000 cubic feet per second, or 25 per cent greater than that of March, 1916. This is the largest flood, in view of the probability of its occurrence, against which it would be economically advisable to provide protection. Even in the event of a heavier flood the loss therefrom would be considerably reduced by the project.

2. The expenditure required for the improvement—estimated at $500,000—is justified by the benefits it will provide.

3. The lands along the river above the limits of the improvement will be benefited during floods by a slight reduction in stage, and inasmuch as the rate of flow will not be increased by it the lands below its limits will not be damaged through an increase in flood heights.

4. It will not appreciably reduce the stages obtaining in the river during periods of low and ordinary flow, but will produce a material reduction in stage during floods.

5. Owing to the fact that during periods of small flow most of the water will be required for the operation of the Goddard power plant, only a relatively small amount, during such periods, can be diverted through the new channel. The amount, however, will probably be sufficient to prevent stagnation and its unsanitary effects.

6. As the improvement is of only local interest it should be administered by local authority. It can probably be handled best through the formation of an improvement district.

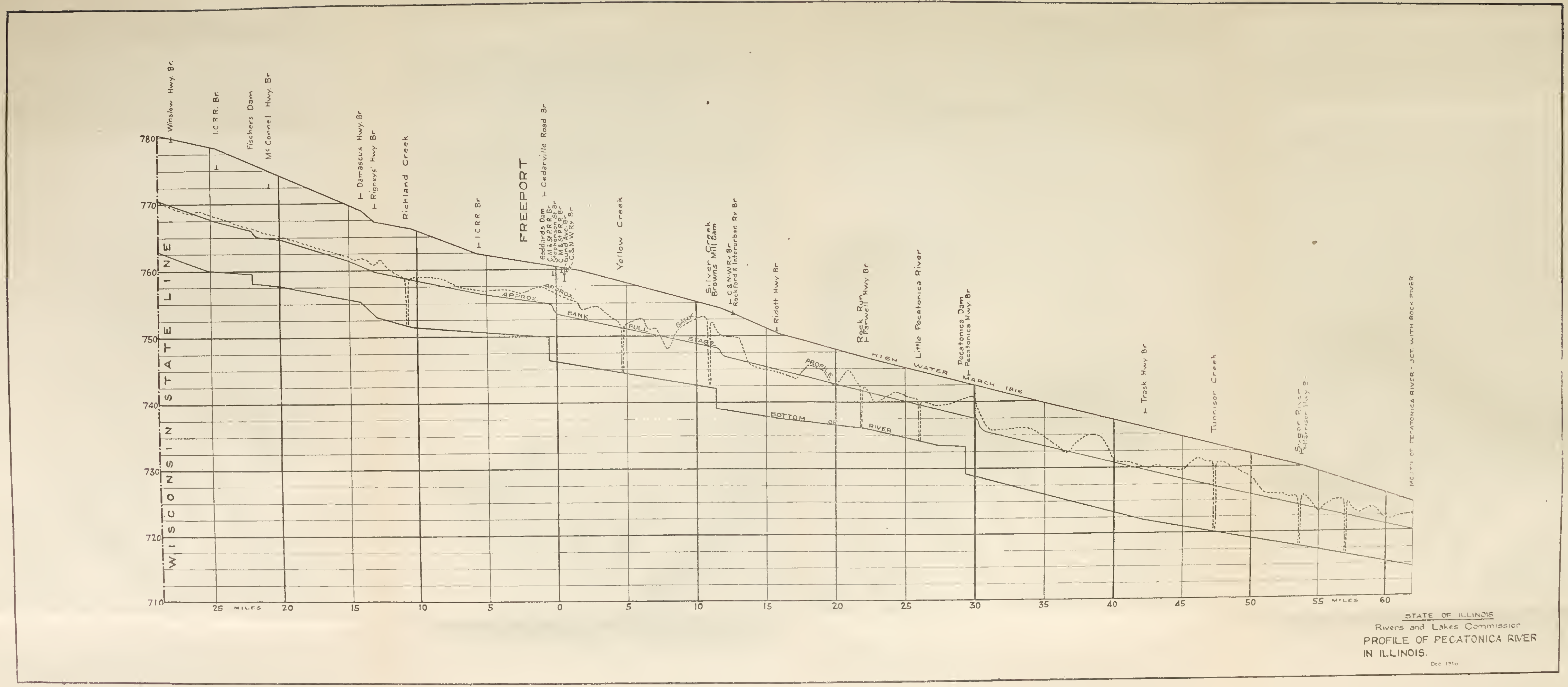

STATE OF ILLINOIS
Rivers and Lakes Commission
PROFILE OF PECATONICA RIVER IN ILLINOIS.
WISCONSIN STATE LINE
FREEPORT
Winslow Hwy. Br.
I.C.R.R. Br.
Fischers Dam
McConnel Hwy. Br.
Damascus Hwy. Br.
Rigneys' Hwy. Br.
Richland Creek
I.C.R.R. Br.
Cedarville Road Br.
Yellow Creek
Silver Creek
Browns Mill Dam
Ridott Hwy. Br.
Rock Run
Farwell Hwy. Br.
Little Pecatonica River
Pecatonica Dam
Pecatonica Hwy. Br.
Trask Hwy. Br.
Tunnison Creek
Sugar River
HIGH WATER MARCH 1916
APPROX. BANK FULL STAGE
PROFILE
BOTTOM OF RIVER
MILES
780
770
760
750
740
730
720
710
25
20
15
10
5
0
5
10
15
20
25
30
35
40
45
50
55
60

PLATE IX.


STATE OF ILLINOIS
Rivers and Lakes Commission
MAP OF
EAST FREEPORT
SHOWING PROPOSED METHOD OF FLOOD PROTECTION
Chicago Ill
Taylor Park
PECATONICA
RIVER
Slough
Proposed Levee
Levee if necessary
Goddards Dam
Moline Plow Works
Foundry
C & N W Ry Shops
Stephenson St
Taylor Ave
Harris St
Henderson Street
2°30' Curve
Center Line of Proposed Channel
Extend Levee to high ground
Gund Ave

PLATE X.

LIST OF BENCH MARKS ON PECATONICA RIVER.

	Elevation.
1. Rockton, Ill.— In yard of Town Hall, northeast corner, iron post Stamped Ill. 1915, 741	741.100
2. Rockton—1 mile south by 1.5 miles west of, at T-Road south at northwest corner Sec. 26, T. 46 N., R. 1 E. by S. E., fence corner, iron post Stamped Ill. 1915, 743	742.616
3. Harrison—2.5 miles east by 0.5 miles south of, at T-Road south, opposite Bate's School north of center of Sec. 32, T. 46 N., R. 1 E. by S. W., fence corner, iron post Stamped Ill. 1915, 741	740.942
4. Harrison—550 feet east of bridge over Pecatonica River on north side of east and west road in line with center of road south, iron post Stamped 1915, 734	733.829
5. Trask Highway Bridge—T. 27 N., R. 11 E., near northeast corner of Sec. 6, north end bridge, copper nail in elm tree	738.51
6. Pecatonica—0.3 mile of, northeast end of concrete bridge over Pecatonica River, on top of concrete guard rail chiseled square	751.24
7. T. 27 N., R. 9 E., center of S. E. ¼ Sec. 23, at road forks, 75 feet south of center line of road west at southwest corner of yard belonging to J. P. Reider—iron post stamped 747	746.883
8. 1.0 miles north of Ridott—At steel bridge over Pecatonica River, top of northeast wing wall of north abutment, chiseled square	752.35
9. Ridott—1.5 miles south by 2.5 miles west of, at T-Road north in yard of State Road Reform Church, nail in cherry tree	775.36
10. Freeport—Postoffice Building, south entrance, west end of top step, bronze tablets stamped 781	780.871
11. Freeport—Chiseled square in top of stone wall on north line of C. & N. W. R. R. right of way 5 feet east of east line of Stephenson St. bridge	762.201
12. Cross on downstream wing wall of left abutment of Harlam Bridge over Pecatonica River in Sec. 15, T. 27 N., R. 7 E. of 4 P. M.	765.899
13. Cross upstream wing wall of left abutment of Rigney's Bridge over Pecatonica River on north line of Sec. 9, T. 27 N., R. 7 E. of 4th P. M.	768.208
14. Cross on downstream side of right abutment of Damascus Highway Bridge over Pecatonica River in Sec. 4, T. 27 N., R. 7 E. of 4th P. M.	770.776
15. Cross on upstream wing wall of left abutment of McConnell Highway Bridge near McConnell	774.44
16. Cross on upstream wing wall of Winslow Highway Bridge over Pecatonica River at Winslow	782.10
15a. Bolt on guard rail on upstream side, right bank on I. C. R. R. Bridge below Winslow	778.55
11a. Freeport—Cross on upstream wing wall of left abutment of Cedarville Road Bridge over Pecatonica River	771.093

PUBLICATIONS ISSUED BY THE RIVERS AND LAKES COMMISSION OF ILLINOIS.

Bulletin No. 1—
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